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DEPTH-FINDING IMAGING DEVICE

Description

[0001] This invention concerns the general claimed device and thereby deals with the measurement of the distance of objects using frequency shifted feedback emitters.

[0002] Techniques of measuring distances optically have been familiar for a long time. Besides echo sounding measurements, in which short light pulses are transmitted and the time elapsed until the backscattered or reflected pulse is measured, others familiar techniques involve interferometric processes.

[0003] An interferometric process entails splitting a light beam into a reference light beam and an object light beam. The object light beam is irradiated onto an object and reflected back from the object. The reference light beam and the object light beam are then superimposed on a light sensor and the distance to the object is derived from the superimposed signal. According to the configuration, this procedure produces very precise measurements; however, the depth measurement of extended objects at different locations creates difficulties.

[0004] Performing distance measurements with frequency deviation feedback lasers and frequency shifted feedback lasers (FSF laser) is also known. Examples of the FSF laser are to be found in

the writings of F.V. Kowalski, P.D. Hale and S.J. Shattil "Broadband continuous-wave lasers," Opt. Lett. 13, 622 (1988), and P.D. Hale and F.V. Kowalski "Output characteristics of a frequency shifted feedback laser: theory and experiment" IEE J. Quantum Electron. 26, 1845 (1990) as well as K. NAKAMURA, T. MIYAHARA, M. YOSHIDA, T. HARA and H. ITO "A new technique of optical ranging by a frequency-shifted feedback laser," IEEE Photonics Technology Letters, Volume 10, 1998 Pages 1772 pp. An example of the application of such a laser for distance measurement is described in detail in the article "Obervation of a highly phase-correlated chirped frequency comb output from a frequency-shifted feedback laser" by K. NAKAMURA, T. MIYAHARA and H. ITO, Applied Physics Letters, Volume 72, No. 21, pages 2631 pp. and in the article "Spectral Characteristics of an All Solid-State Frequency-Shifted Feedback Laser" by K. NAKAMURA, F. ABE, K. KASAHARA, T. HARA, M. SATO and H. ITO in IEEE-JOURNAL OF QUANTUM ELECTRONICS, Volume 33, pages 103 pp. Also refer to I.C.M. Littler, S. Balle and K. Bergmann "The cw modeless laser: spectral control, performance data and build-up dynamics" Opt. Commun. 88, 514 (1992) and S. Balle, F.V. Kowalski and K. Bergmann "Frequency shifted feedback dye laser operating at small frequency shift" Opt. Commun. 102, 166 (1993) and G. Bonnet, S. Balle, Th. Kraft and K. Bergmann "Dynamics and self-modelocking of a Titanium-Sapphire laser with intracvacity[sic] frequency shift" Opt. Commun. 123, 790 (1996). The three latter documents expand on FSF lasers according to the current state of technology. These documents are also comprehensively categorized by reference in DE 100 45 535 for purposes of disclosure. A configuration in which an FSF laser is used for locally resolved distance measurement is described in DE 100 45 535.2

and PCT/EP 01/10416.

[0005] The principle of distance measurement with an FSF laser, which also contains an acousto-optical modulator in its resonator, in addition to an amplification medium, may be briefly presented as follows: amplification of light from the light waves entering into the amplification medium occurs for each frequency in which the amplification is greater than 1. For all other frequencies the light is diminished as usual. The optical resonator now has preferred frequencies, similar to a vibrating string, so-called resonator modes. Each resonator mode has a specific frequency, i.e. it corresponds to light of a precisely specified wavelength. Each resonator mode, in which the amplification of the amplifying medium is greater than 1, will now be emitted as a preference.

[0006] This is principally the behavior of a laser without an acousto-optical modulator. If the acousto-optical modulator now becomes excited, the material oscillations create a moving grid that varies in its density at various places; the light traveling around in the resonator is diffracted at this density grid, whereby an interaction of the light photons with the photons characterizing the density oscillations of the acouto-optical modulator occurs, which shifts the frequency of the diffracted light by the excitation frequency of the acousto-optical modulator. This leads to the laser modes shifting in time insignificantly in the frequency, changing the frequency of a mode in time; when there is more than one mode, this also applies to all modes that are oscillating in the resonator. This means, however, that according to the extent the amplification 1 of the amplification profile runs, the intensities of the individual oscillating modes are

different and that the mode intensity changes with the frequency. It is makes sense that the frequencies change for all modes equally with time. In other words, light that is emitted at different times will possess different frequencies.

[0007] Light beams that are irradiated over optical paths of varying length now flow to a location similar to a detector, i.e. they were also emitted at different times from the laser, so there must be a frequency difference between the two. This frequency difference can be detected as a beat frequency on a photo-sensitive element. The length of distance traveled can be determined from the beat frequency.

[0008] The familiar measuring set-up is described in the documents referred to above.

[0009] In practice, it has been shown that the signals at the measuring receiver are strongly degraded by a high noise level. If the distance that is to be determined is fixed, a single sharp line without noise in the beat frequency would be observed. In reality, however, it turns out that instead that a very broad structure instead of a sharp line is received with FSF lasers, which severely impairs the quality of the received measurement.

[0010] It is desirable to change the known setups and processes in such a way that the applicability can be increased.

[0011] The task of this invention is to make something new available for commercial application.

[0012] Claims for the solution to this task are made in independent form.

[0013] According to a first essential aspect of this invention, a device for the locally resolved determination of object distance is proposed with a frequency shifted feedback emitter for object irradiation with beams that can be used to determine distance and a position-sensitive object detection sensor, whereby the frequency shifted feedback emitter used for object irradiation is configured with a means for increasing emission frequency component beat intensity and the position-sensitive object detection sensor for detecting the beat intensity from the object and the beam that does not enter from the object.

[0014] Accordingly, it was not only recognized that the prevailing assumption in the interpretation of the state of technology that the beat portions coming from individual modes of the frequency shifted lasers would add up is not correct; rather, they interfere destructively. Surprisingly, the signal that can be achieved in the current state of technology with FSF lasers rests on the fact that noise in the operation of the known lasers, i.e. occurrence of fluctuation of intensity and/or phase, which prevents the occurrence of a - theoretically awaiting more exact analysis - completely destructive interference of the frequency components that are coherent to one another, as would otherwise occur. For measurements using FSF lasers, according to the current state of technology, conditional noise

accordingly appears not to be a consequence of the noise of the laser; rather, it is the actual measurement signals themselves that are conditioned by the noise of the lasers, i.e. their inherent fluctuations. Based on this knowledge it is now not only proposed that the emitter be equipped with means to increase the intensity of the beat vibration of frequency components of the emitted beam, but it is also specified how this knowledge can better be used to improve locally resolved object distance measurement.

[0015] In a preferred variation, the means for increasing emission frequency component beat intensity are configured as a means for increasing non-stochastic emission frequency component beat intensity, the means will therefore condition an intensity increase brought about by spontaneous emission, in particular in the amplification medium.

[0016] Typically an injection light source is used that injects light into the emitter, i.e. a seed emission field is arranged there. As an alternative, it would also be possible to interfere with complete destructive interference of frequency components via the measurement conditioned by spontaneous emission in the stationary operating condition by modulating the pump light somewhat, which is typically less preferred due to the level duration, etc. or by bringing about a somewhat fast loss mechanism in the amplification medium itself. The presence of an injection light source, however, is especially advantageous because it is an easy to build option through which a number of advantageous configurations can be realized.

[0017] A particularly advantageous variation for an injection light source is an injection laser. The emission of the laser can be guided into the resonator, in particular, in and/or to the amplification medium of the frequency shifted feedback emitter.

[0018] It is preferred when the injection light source emits light at a wavelength that is close to the wavelength at which the amplification of the amplification medium of the frequency shifted feedback emitter is at 1; it may optionally be irradiated close to the upper and/or lower threshold wavelength. The frequency of the injected light emission will typically be within the range in which the amplification G is greater than 1 and not outside of that range. For seed radiation injected very close to the threshold, and, particularly, modulation of the same, this threshold may temporarily be exceeded. It would always be preferable to select the irradiation frequency in such a way that amplification occurs no later than after a few resonator revolutions.

[0019] It is preferred when the injection light source emits narrowband irradiation whereby the narrowband radiation is incorporated into the amplification bandwidth of the amplification medium of the frequency shifted feedback emitter. In this instance, narrowband can refer to a bandwidth no greater than 5%, preferably not over 1% of the amplification bandwidth. In a particularly preferred variation, a single-mode injection laser with a precisely defined, modulating frequency and/or amplitude can be used for the injection.

[0020] The injection light irradiation preferably varies with regard to intensity and/or phase. This variation can occur due to a regular modulation, i.e. modulation of intensity and/or phase subject to preset principle moderation or limitations, which do not necessarily need to be uniform.

[0021] It is especially preferred when the modulation is not constant but when the intensity and/or the phase of the modulation of the injection light emission varies with time, which occurs best in a periodic manner. It is especially preferred when the frequency of the intensity modulation is changed within specified intervals because a linear variation of the modulation frequency of the injection light emission significantly simplifies an assessment of received beat vibration signals for measuring distance.

[0022] When a modulation of the emission emitting from the injection light source with respect to phase and/or intensity is performed, it is preferred when the frequency of this modulation lies close to the frequency occurring from the so-called chirp rate and the distance that is determined with the emission source immediately. The chirp rate is provided by the frequency of the acousto-optical or other modulator within the frequency shifted feedback emission source referring to the revolution period of the emission in the resonator of this source.

[0023] It may be mentioned that the emission source is typically a frequency shifted feedback laser. This may work in particular in infrared ranges that are

safe to the eye. The wavelength ranges that are technologically well open and particularly cost-efficient for telecommunications devices may also be used for purposes of this invention, which opens the possibility of accessing cost-effective available elements for designing configurations and devices.

[0024] A device is preferred in which the frequency shifting feedback emission source is formed by a laser and the means for increasing emission frequency component beat vibration intensity is a frequency-modulated seed laser with seed light irradiating into the first laser, whereby the device also includes a means to adapt the frequency of the seed laser frequency modulation to distances to be measured. In other words, it is proposed that the device for locally resolved object distance measurement includes a tunable seed laser and the beat signal is determined depending on the seed laser tuning.

[0025] It is especially preferred when the seed frequency is gradually modified in order to provide sufficient time for setting a stabile beat and its identification on the sensor. The seed frequency can be modified accordingly in steps and be kept constant for a specific measurement period. It is also possible to wobble the seed frequency around a specific value, which prevents frequency hopping of the seed frequency tuning, lying in such a way the specific distances can not be determined and thereby no and/or only inexact distances for individual objects or object partial ranges can be determined. The seed frequency can also be changed systematically in different pass-throughs

with different steps and the same whereby it is understood that the object distance is then determined taking into consideration the signals from several transmissions.

[0026] It is particularly advantageous when the object detection sensor signals related to beat intensity detected using the object detector sensor are filtered. A filter can be formed in particular for filtering out only the alternating signal portions. It is particularly advantageous that a relevant signal only occurs in the range of the seed frequency and therefore can be filtered on this seed frequency in a narrow band, whereby the filter can run with the seed frequency and/or has a specific narrow band. It may be pointed out that artifacts can lead to sharp frequency components being present in a high portion in the conditioned object detection sensor signal whereby this frequency components can be different from the seed frequency. Such interference signals may be filtered out particularly well with narrowband filters.

[0027] The object detection sensor signal conditioning typically includes a signal amplification, whereby it is particularly preferred to arrange the amplification behind the filter step because very strong amplification is possible there, which also allows very weak beat signals to still be evaluated. It can be seen that the regulated and/or controlled signal conditioning, in particular with respect to the regulated and/or amplification set in another way is particularly preferred to be able to also measure at great distances. In particular it is possible to prescribe a dependence of the respective amplification from the relevant seed frequency

in order to take into consideration in such a way that a given seed frequency corresponds to a specific distance and, accordingly, a distance-proportional amplification with, for example, 1/r2- or 1/r4-.

[0028] Typically, therefore, the signature of the object detection sensor signal will be detected depending on the seed frequency tuning. An arrangement can be made for the maximum value of the object detection sensor signal to be determined during the seed frequency tuning whereby, as previously mentioned, the seed frequency tuning can proceed gradually or an effective value is ascertained that is received as a real effective value after rectification and low-pass filtering of the preferred band-passed filtered amplified object detection sensor signal and/or the effective value can be determined in a specific frequency window for purposes of distance measurement.

[0029] It is possible to draw out differentiations of the object detection sensor signal with the seed frequency modification or, insofar as these occur with the time, the variation of the object detection sensor signal with the time for the purpose of measuring distance. When noise can call forth fast signal fluctuations and thereby large differentiations, it is possible to diminish the influence of noise through simultaneous viewing of a signal comparator output that ensures that changes of the differentiations be taken into consideration only when the conditioned object detection sensor signal is sufficiently large because in such cases it can be assumed that there is no exclusive noise influence. The scoring can ascertain a distance measurement value with regard to the time between a preset characteristic, such as achieving a maximum in the object

detection sensor signal from the beginning of a seed frequency sweep or a successive frequency change. That this can happen when using analog circuits with which the respective maximum is maintained and a "maximum achieved signal" is generated, as soon as an object detection sensor signal no longer climbs in order to enable the registration of a seed frequency related or sweep time duration signal counter value into a digital register that exceeds this "maximum achieved signal, has been mentioned.

[0030] An especially preferred variation consists using an FSF laser emitting in infrared with frequency shifted feedback as an emission source. On the one hand this provides an operation in corresponding infrared ranges that is inherently safe to the eyes and on the other hand makes possible irradiation of an object simultaneously in visible light without changing the visible colors there. It may be mentioned that it is possible to determine first the oscillation intensity and then capture the natural light from the object with one and the same object detection sensor in time consecutively. In such a case it is clearly preferable to use different signal conditionings for signals from one and the same pixel. There is also another possibility to perform object detection with a multi-pixel chip such as a CMOS or CCCD array, which in particular is known for being able to be configured for multi-color detection, whereby the preferred, but not required, infrared irradiation of the object or their superimpositions on the chip with an emission portion irradiating via a reference path can be detected as a "color." When separate sensor element fields for different colors or IR and visible light are used,

image position agreements can be conducted in the familiar way through image position correction steps.

[0031] The invention will now be described in the following as examples using illustrations. These illustrations show:

Fig. 1 a schematic design of a frequency shifted feedback emission source for a device that conforms to the invention;

Fig. 2 the frequency variation of a single laser mode when using a linear chirp over time;

Fig. 3 the synchronous variation of all components (modes) of an emission light source with frequency shifted feedback;

Fig. 4 the frequency spectrum of an FSF laser for the given amplification curve (top of image);

Fig. 5 a schematic design for a distance measurement with a configuration that conforms to the invention;

Fig. 6 a grayscale display of a beat frequency spectrum, as can be achieved from the current state of technology, with an artifact structures that are independent of position and a weak measurement signal that is recognizable as stripes running diagonally through the image;

Fig. 7 an example of a beat frequency signal dependent on a seed emission frequency modulation.

Fig. 8 an example of a design of a device that conforms to the invention.

[0032] As shown in Fig. 1 a general frequency shifted feedback emission source 1 designated as 1 includes a means 2 for increasing emission frequency component beat intensity.

[0033] The frequency shifted feedback emission source 1 in this example is a ring laser with frequency shifted feedback. The ring resonator of the ring laser 1 is formed through two high reflecting mirrors 1a, 1b and an acousto-optical modulator 1c to which a piezo element 1c1 as an actuator and input and outputs prisms 1c2, 1c3 are arranged and then configured in the resonator ring in such a way that the zeroed diffraction order, displayed as a beam 3 that can be coupled out while the first diffraction order guides the light circulating in the resonator. The acousto-optical modulator 1c is selected in such a way that the diffractions efficients of more than 90% result for the first diffraction order frequency shifted in the familiar way through the acousto-optical modulation. The geometry is also selected in such a way that the prisms 1c2, 1c3 arranged on the acousto-optical modulator 1c are compensated with regard to their dispersion and is still possible in a compact design.

[0034] A fiber medium 1d is configured between both high-reflecting mirrors 1a and 1b to which a fiber

launch and catcher optics 1d1 and 1d2 are arranged. Energy from a point laser designed here as a diode laser (not shown) is irradiated into the fiber so that it can be used as an amplification medium. The launch occurs on a fiber coupler 1e. The displayed fiber is a traditional ytterbium fiber with a large useable amplification bandwidth of at least 70 nm, in this example, in the spectral range around 1.2 μm; such elements are easily available from the area of optical telecommunications, exactly like other, equally applicable configurations, for example, fiber lasers on the basis of YAG at 1.06 μm with a few nm of bandwidth or erbium of 1.5μm could be used.

[0035] The configuration of the FSF laser, as it has been described up to this point, is essentially traditional. Means for increasing emission frequency component beat intensity will be used. For that purpose there is a fiber coupler 2a that is used to couple injection light into the fiber, indicated in 2b, using a launch optic 2c. The injection light 2b comes from an injection laser (not shown) that with regard to its amplitude and the phase of the optical carrier can be modulated in a temporally variable manner. The injection or seed laser emits radiation whose wavelength lies up close to the lower position G=1 of the amplification profile of the FSF ring laser 1 or the fiber 1d displayed for the up-chirp, compare Fig. 4, where in the upper portion of the image the amplification profile is illustrated as running lines, together with the amplification threshold 1, which is drawn horizontally and whereby the optical carrier frequency of the seed laser is entered as a vertical, hash line.

[0036] It can be mentioned at the same time that instead of, and/or besides, a launch via a fiber coupler 2a, a launch of an injection light beam through one of the high-reflecting mirrors would also be possible, as indicated with mirror 1a through beam 2b2, and/or a launch could occur into the acousto-optical modulator, as indicated by arrow 2b3. For the sake of completeness, it is also indicated here that the pump light that is different in this instance from the injection light, indicated with 1e1, can not only be launched via a fiber coupler into the amplifying fiber 1d from the pump light beam 1e1, but, for example, a pump light launch is possible via the high-reflecting mirror as indicated by the beam 1e2 close to the mirror 1b.

[0037] This configuration is operated as follows:

A pump light is irradiated on the fiber 1d to bring about an inversion that makes laser operation possible. Then the piezo driver 1c1 of the acousto-optical modulator begins to oscillate so that the ring of the frequency shifted feedback laser is closed. Light, that is now emitted from the fiber can now run over the mirror 1a, through the prism 1c2 and the acousto-optical modulator 1c1 and the prism 1c3. The major portion of this light will thereby irradiated into the fiber 1d corresponding to the high diffraction efficiency of the acouto-optical modulator linked to the mirror 1b1.

[0038] When passing through the acousto-optical modulator 1c, the frequency of the light changes simultaneously. The light that has run in the direction of the to the acousto-optical modulator

with a preset frequency at the mirror 1a, will therefore strike at the other high-reflecting mirror 1b with a shifted frequency or wavelength. This light with shifted frequency is amplified in the fiber 1d, runs again over the mirror 1a under further frequency shifting through the acousto-optical modulator 1c to the mirror 1b, etc. This leads to the shifting of the frequency upon each pass. The speed used to change the frequency depends on the time it takes for the light to make a pass and how strong the frequency shift in the acousto-optical modulator is. The shift occurs for all components or modes that can be amplified in the resonator in the same way so that the frequency comb represented by the modes of the FSF laser are gradually shifted in a synchronous manner. There is a so-called "chirp." This is displayed in Fig. 3, whereas Fig. 2 displays the variation of the frequency for a given linear chirp.

[0039] This light is now used to measure distances. This will only be discussed in principle first for a not yet locally resolved interferometer configuration, as displayed in Fig. 5, in which the invention light source 1, a beam segmenting element 4 in the catcher beam 3 of the light source1, a reference path 6 to a reference surface 6' and measurement path 7 to a measurement object 7' are displayed, whereby the beams from the reference object 6' and from the measurement object 7' are guided to a detector 5.

[0040] The situation that arises in such a configuration for taking the seed source into operation on the detector, can be seen in image 6. A grayscale display of the beat frequency spectrum is displayed

for a laser configuration as a function of the path difference ΔL of the arms 6 and 7 of the measurement configuration. In the grayscale display, the lines can be seen that are position-independent and do not vary with the path difference ΔL and thereby run horizontally in the image; the lines are conditioned by a standing wave portion in the acousto-optical modulator and repeat themselves after the resonator pass run time. Further, it can be seen that the actual measurement signal has strong noise interference, which runs diagonally as a dark stripe through the image.

[0041] Now the injection light source is taken into operation and with a carrier frequency close to the lower range of the amplification curve, i.e. just still inside that range, in which the amplification is greater than 1. The optical carrier frequency this is drawn vertically is modulated, and amplitude modulated in this example, whereby the modulation itself is also not constant, but varies with a frequency that is nearly determined from the so-called chip rate α, i.e. the frequency shift per resonator pass divided by the resonator pass time and is further determined by the light run time along the path difference ΔL between the measurement beam path and the reference beam path as in the design of Fig. 5. The modulation frequency of the injection light is therefore not held constant, but varies around this so-called signature value, i.e. around the value this results from the chirp rate α and ΔL through the formula

$$\Delta\nu = \alpha \times \Delta L \times c^{-1}$$

whereby c is the light speed. The modulation frequency is changed around this signature frequency and is preferred in a linear saw tooth form. An intensity is yielded at the detector, as is displayed in Fig. 7. It turns out that a very significantly manifested, sharp intensity peak of the beat signal can be obtained, i.e. the signal is degraded very little from noise and in particular shows a minor degree of noise and thereby a more precise measurement than has been possible up to this point in the current state of technology. It is significant that the injection emission modulation and the beat frequency intensity are tightly linked to one another and a beat frequency intensity maximum is then achieved when the injection modulation frequency corresponds to the frequency expected for a given path difference taking the chirp rate into account.

[0042] Presently this is justified as follows: Through the injection of the irradiation of the injection laser at the edge of the amplification range, modes are shifted in the resonator in steps $\Delta\nu_{AOM}$ over the entire amplification bandwidth so that the laser does not end up in a stationary, practically noise-free equilibrium at which it otherwise would sink. Accordingly, it seems that the traditional image of the coming into position of the beat spectrum is incorrect and actually in a noise-free instance the intensity of a beat would disappear.

[0043] In can now be determined that the structure width of the received signal structure is determined by the amplification bandwidth, i.e. a high bandwidth of the emission light source with the frequency shifted feedback, i.e. of the FSF laser, leads to a good spatial resolution. Because additionally

the distance measurement precision is essentially determined by the chirp magnitude, it is desirable to select a large frequency shift through the acousto-optical modulator and a small laser resonator length of the FSF laser resonator.

[0044] It can be determined that during a distance measurement and, if necessary, during successive distance measurements at a specific time interval, a very high degree of precision can be achieved even during speed and/or acceleration measurements that essentially only depend on the driver frequency consistency of the acousto-optical modulator, as well as the laser resonator length stability during the measurement time. In addition, only magnitudes such as the precision of the beat frequency determination need to be taken into consideration. It is evident that systematic resolutions and precisions of 10^{-6} - 10^{-8} can be achieved. Through the significantly improved signal noise ratio it is also possible to perform measurements using very low power levels because only a high frequency portion in the detected signal must be detected as a beat and this portion consists of familiar or nearly familiar frequencies.

[0045] As shown in Fig. 8, a device numbered 100 for locally resolved object distance measurement 100 includes a frequency shifted feedback emission source 101 for irradiation of an object 102 with irradiation 103 that can be used for distance measurement and a position-sensitive sensor 104 whereby a seed laser 105 is allocated to the frequency shifted feedback emission source 101, which in this case is configured as an infrared frequency shifted feedback laser 101; the seed laser feeds modulated

and gradually fluctuating seed ling into the amplification medium of the FSF laser 101. The object detection sensor 104 receives on the one hand the irradiation 103 from the object, on the other hand, reference ling via a beam splitter unit 106 via a reference path of predetermined length from the FSF laser 101 as well as visible light from the object 102, which is indicated by beams 107. A reference may be made to the fact that directing of the FSF light from the emission source 101 to the object 102, and traditional optical elements, as indicated with 109, can be used for collecting light or distance-measuring irradiation from the object 108 to the object detection sensor 104, for splitting the beams, a dimmer, etc. The design can conform to traditional rules of the current state of technology taking into consideration the respective wavelengths, desired image properties, etc. A reference may be made to the fact that a configuration is possible where an all-around monitoring and detection is possible, the objects forming a sphere or partial sphere around the device, which is possible using a suitable mechanical rotation and/or rocker seating for all or a part of the device components.

[0046] As can be seen from the general principles of the FSF laser using seed injection described above, the result will be a beat signal on the sensor 104 through the superimposition of the reference light and the light 108 received from the irradiated object 102. This signal will become maximum when the seed frequency that is used to modulate the seed laser 105 results from the chirp rate of the irradiation of the frequency shifted feedback emission source 101 and the additional distance traveled from the object beam 108 - 103

according to the previously stated formula. An evaluation configuration 110 is allocated to each pixel of the sensor 107, laid out here as a CMOS array, with which the electric signal from each pixel of the object detection sensor 104 is filtered in narrow band and conditioned by appropriate amplification and then fed onto a maximum holding circuit arranged in the evaluation configuration 110, which at each point in time compares an immediately value of the conditioned signal with the previously observed maximum and provides a stop signal, when such a maximum is not reached as indicated by the decline of the signal. The stop signal is forwarded to a counter which begins to count at the beginning of a seed frequency signal sweeps over several, gradually modified seed signal frequencies. The stop signal stored for each pixel corresponds to a frequency at which the object detection sensor signal signature shows its maximum. By referencing the known chirp rate, the geometric relationships, in particular regarding the reference beam path length, and the temporal seed frequency signal ratio, a corresponding distance value of the object range imaged on the pixel can be determine for each pixel. Parallel to determining the distance of the object, as described above, the traditional two-dimensional image can be obtained digitally and using appropriate electronic circuitry, for example, a superimposition of the images can be achieved. In this way, the depth values can be determined at one point in a recorded two-dimensional surface image and a spatial image can be obtained. A reference may be made to the fact that illumination fields can be determined very will using this configuration, which makes

images synthesis using retrieval of the shape of recorded environments, which then serve as objects, much easier.